THE SPECTRAL SENSITIVITY OF DYTISCUS FASCIVENTRIS

BY THEODORE LOUIS JAHN AND VERNER JOHN WULFF
DEPARTMENTS OF ZOOLOGY AND PHYSIOLOGY, STATE UNIVERSITY OF IOWA AND DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY, UNIVERSITY OF ILLINOIS

The spectral sensitivity of various insects has been determined by a number of methods, most of which are based on the behavior pattern of the experimental animal (review, Weiss, 1943, 1945). Recently, however, the electroretinogram has been used as an index of spectral sensitivity of grasshoppers and moths (Crescitelli and Jahn, 1939; Jahn and Crescitelli, 1939; Jahn, 1946). In certain beetles (*e.g.*, *Dytiscus* and *Hydrous*) there are diurnal changes in several aspects of visual function, and these can be detected through changes in the electroretinogram (Jahn and Crescitelli, 1940; Jahn and Wulff, 1941a, 1941b, 1943; Wulff and Jahn, 1943). Therefore, it was considered worthwhile to determine by means of the electroretinogram the spectral sensitivity of *Dytiscus fasciventris* during the phases of its diurnal rhythm. The data resulting from this investigation are given in the present paper.

METHOD

The sensitivity to various wave length bands in the visible spectrum of the beetles was determined by measuring the electrical response of the eye. The technique used for stimulating and recording from the eye has been described previously (Crescitelli and Jahn, 1939). The wave length of the stimulating light was controlled by a series of Corning glass filters used in appropriate combinations to yield the following wave bands:

Filter Comb.	Width of Band mμ	Peak of Band mμ
1	680–740	720
2	640–680	645
3	600–640	620
4	560–600	575
5	530–570	545
6	500–550	515
7	470–520	490
8	470–470	440

The energy transmitted by the filter combinations was determined with a thermopile, and the stimulating intensity was varied by use of Wratten neutral tint filters. The animals were maintained in a state of complete dark adaptation throughout the experiments. The exposure duration was 17 milliseconds, and the exposures separated by a time interval of 15 or 20 minutes, depending upon the intensity.

RESULTS

Three or four responses were recorded at different intensities with each filter combination. The magnitude of the initial spike-like deflection of these responses in microvolts (ordinate) were plotted against the common logarithm of the intensity (abscissa), resulting in a curve for each filter combination (Fig. 1), which is part of a sigmoid curve relating the response magnitude to the logarithm of the intensity (Wulff and Jahn, 1943; Wulff, 1943). The resulting family of curves was treated as follows: (1) a constant response magnitude was selected which would intersect all the curves (180 micro-volts in 8 experiments and 90 micro-volts in 2 experiments); (2) a vertical line was dropped from the point of intersection to the abscissa; (3) the logarithm of the intensity corresponding to the points on the abscissa were tabulated opposite the wave length of the peak transmission of the filter combination. These values for 10 experiments are plotted in Figure 2.

In order to examine the results in more compact form the data were manipulated as follows: (1) the reciprocal of the intensities for constant response magnitudes were calculated; (2) the peak value for each curve was set at 100 per cent and the remaining points of each curve were recalculated in terms of this maximum; (3) the values of the reciprocal of the intensity in per cent of maxima were then averaged and tabulated in relation to wave length of the peak transmission by the filter combination, Table I, and plotted in Figure 3. The two uppermost curves (numbered 10 and 3) were obtained from animals in the day phase, and all of the others were obtained from animals in the night phase.

DISCUSSION

The spectral sensitivity curves of Figure 2 are dispersed along the ordinate. These variations may be explained as follows: (1)

eight curves were obtained from animals in the night phase of their diurnal rhythm and two curves were obtained from animals in the day phase. In view of the marked differences in sensitivity of the *Dytiscus* eye during these phases a spread is to be expected in the above instance; (2) the experiments were of long duration (4–6 hours) and, although the times of experimentation

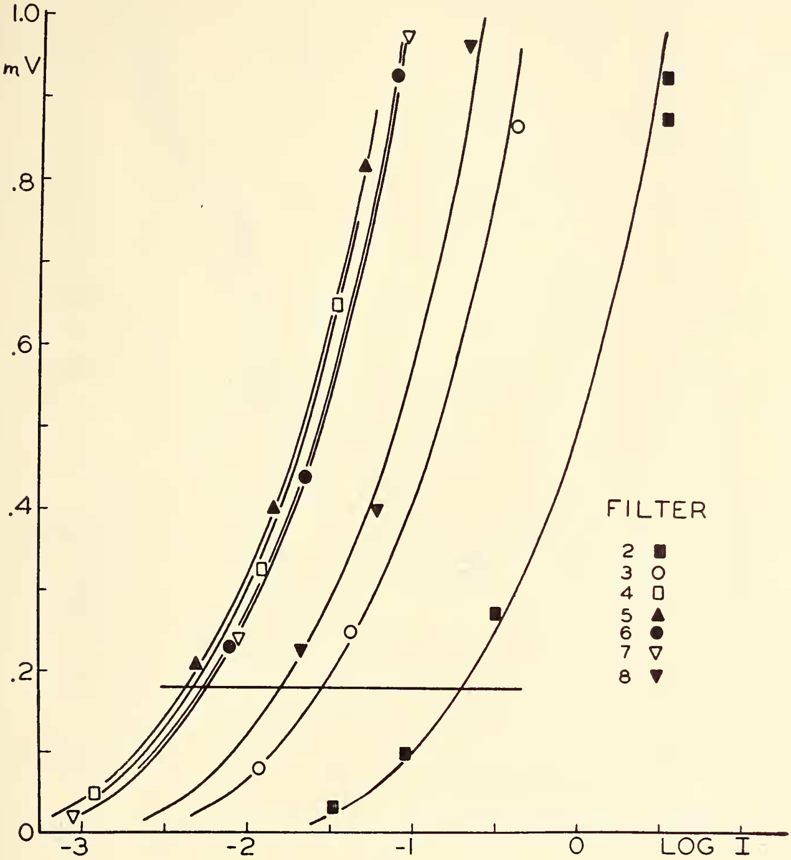

Figure 1. Curves for each filter combination relating the magnitude, in millivolts, of the initial spike-like deflection of the retinal electric response to the common logarithm of the stimulus intensity. These data represent one experiment. The points of intersection of the 180 micro-volt constant response line give the values of Log I for constant magnitude response for each filter combination.

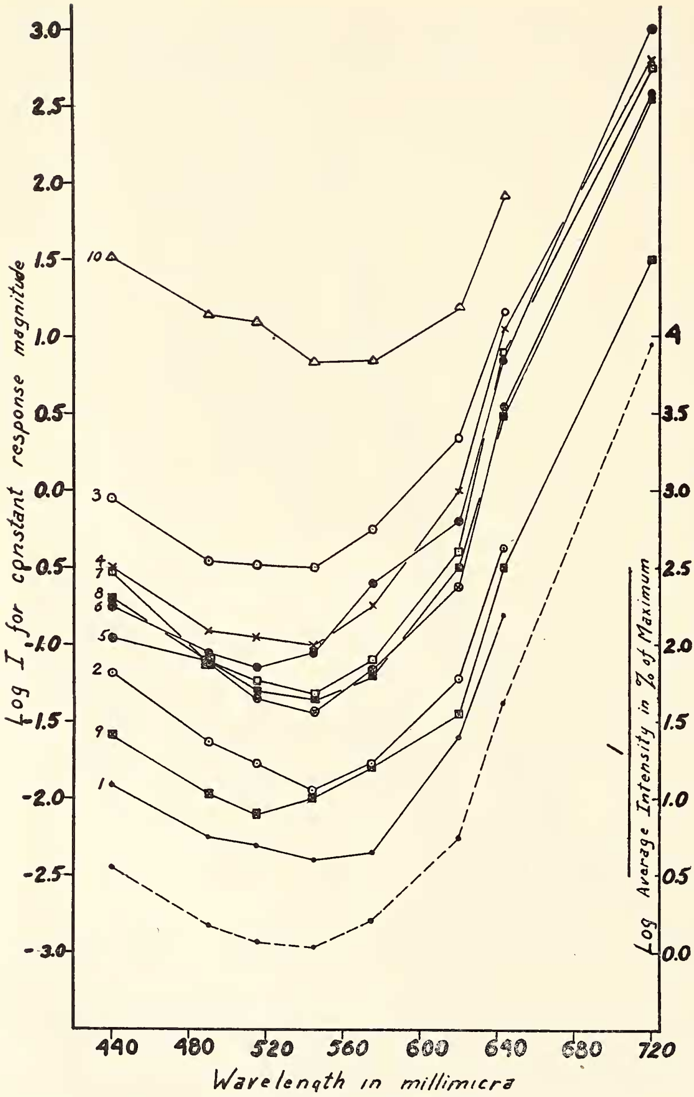

Figure 2. Continuous lines—curves relating the logarithm of the stimulating intensity required to produce a constant magnitude response to the wave length of maximum transmission of each wave length band. Each curve represents an individual experiment and the numbers correspond with the numbers in Table I. Curves 3 and 10 were obtained from animals in the day phase and all others from animals in the night phase. The broken line represents the average of the ten experimental curves.

TABLE I

DATA PLOTTED IN FIGURE 2 RELATING WAVE-LENGTH TO THE LOGARITHM OF INTENSITY FOR CONSTANT MAGNITUDE RESPONSE. LAST COLUMN RELATES WAVE-LENGTH TO LOG RECIPROCALS OF VALUES PLOTTED IN FIGURE 3.

Wave-length of max. transmission filter combination	Logarithm of stimulating intensity for constant magnitude response										Logarithm of reciprocal of average intensity in per cent of maximum
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7	Exp. 8	Exp. 9	Exp. 10	
720 mμ, 1	......	......	......	2.80	2.60	3.0	2.75	2.57	1.50	......	3.96
643 mμ, 2	−0.80	1.16	−0.37	1.07	0.55	0.86	0.65	0.50	−0.62	1.92	1.62
620 mμ, 3	−1.60	0.35	−1.22	0.00	−0.62	−0.18	−0.40	−0.50	−1.45	1.2	0.75
575 mμ, 4	−2.35	−0.25	−1.72	−0.74	−1.16	−0.60	−1.10	−1.20	−1.80	0.85	0.21
545 mμ, 5	−2.40	−0.50	−1.95	−1.00	−1.43	−1.05	−1.32	−1.34	−2.00	0.85	0.04
515 mμ, 6	−2.30	−0.48	−1.77	−0.95	−1.35	−1.15	−1.23	−1.30	−2.10	1.10	0.07
490 mμ, 7	−2.25	−0.45	−1.62	−0.90	−1.16	−1.05	−1.10	−1.10	−1.96	1.15	0.18
440 mμ, 8	−1.90	−0.05	−1.18	0.50	−0.95	−0.74	−0.50	−0.70	−1.58	1.52	0.56

Note: Constant response magnitude is 180 μV, except in Exp. 6 and 10, where it is 90 μV.

were chosen to correspond to the theoretical time of maximum day and night phase, they may have not corresponded to the actual time of maximum day and night phase in each particular beetle; (3) minor variations occurred in the mounting of the animal, placing of the animal in the light beam and in the placing

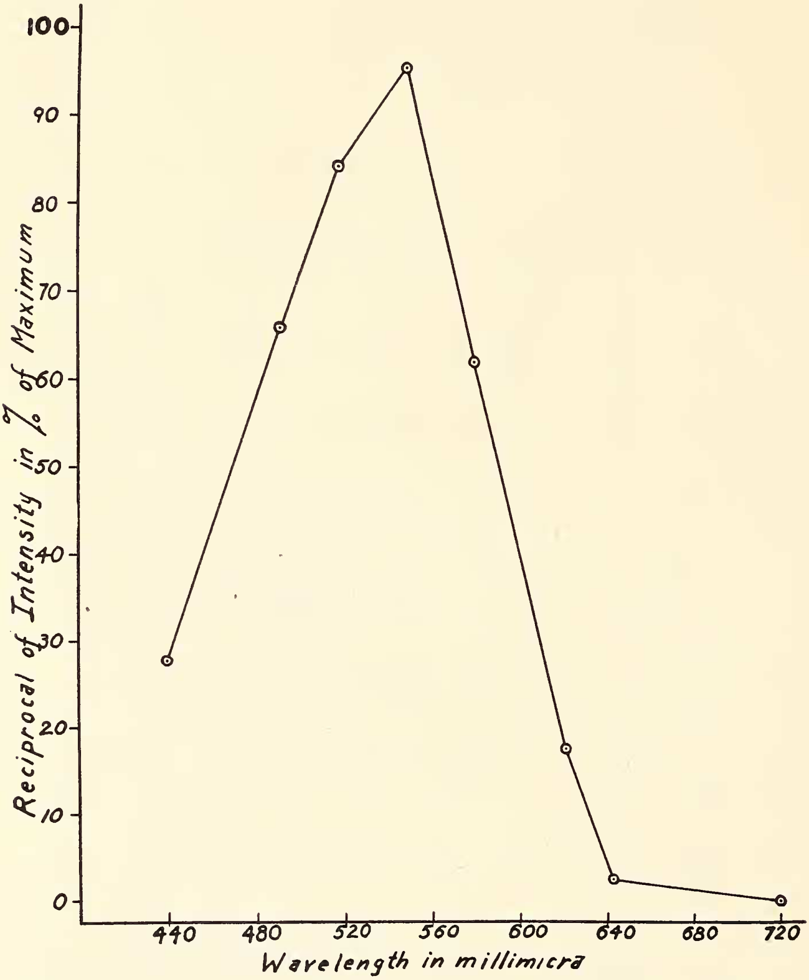

Figure 3. The average spectral sensitivity curve for *Dytiscus* obtained from data presented in Figure 2.

of the filter, and all of these factors would contribute to dispersion along the ordinate.

The curves of Figure 2 resulting from individual experiments are quite uniform with maximal sensitivity in the region 520 to 575 mμ and correspond generally to data from grasshoppers obtained in a similar manner (Crescitelli and Jahn, 1939; Jahn, 1946). In the figures published by Jahn (1946) the data for 500 and 530 mμ were inadvertently transposed from the original data of Crescitelli and Jahn (1939). If this transposition is corrected and the maximum for the grasshopper taken as 530 mμ, then the limits of the data do not permit the assumption of any real differences between *Melanoplus* and *Dytiscus*. At present the data on *Dytiscus* seem to be the most accurate insect spectral sensitivity data obtained by the electrical method.

The data agree well with results of Graham and Hartline (1935) obtained from electrical studies of the *Limulus* photoreceptor and with results obtained from *Cecropia* moth eyes (Jahn and Crescitelli, 1939) using similar techniques. Spectral sensitivity data obtained from behavior studies of insects placed in an environment of equal energy monochromatic wave bands yield data which are grossly similar to that here described but differ in the spectral location of maximal sensitivity. Bertholf (1931) presented data which indicate that for the honey bee the region of maximal sensitivity in the visible spectrum in 553 mμ and for *Drosophila* (1932) the maximum lies at 487 mμ. Weiss and his co-workers (1941, 1942, 1943a, b, and c, 1944a, and b) reported data on a wide variety of insects which indicate sensitivity maxima at 436, 492, 515, 606 and 642 mμ in the visible spectrum, with an average maximal sensitivity in the wave-length band whose peak transmission is at 492 mμ. It is not possible at present to state whether the differences exhibited by the data obtained from behavior and electrical studies are significant or, if so, to what the differences may be attributed.

The data obtained from *Dytiscus fasciventris* indicate that no significant difference exists in the spectral sensitivity of the eye in the day and night phase of its diurnal rhythm. The dispersion on the ordinate may be explained partly on the basis of a different absolute sensitivity of the photoreceptor during the day and night phases (Jahn and Wulff, 1943).

SUMMARY

1. The spectral sensitivity of the dark adapted eye of the beetle, *Dytiscus fasciventris,* was determined by using the electrical response of the photoreceptor as an index of sensitivity.

2. The region of maximal sensitivity in the visible spectrum as indicated by individual data is 520 to 575 mμ. The region of maximal sensitivity as indicated by the averaged data is 530–540 mμ.

3. No significant difference was found in the wave length sensitivity of the photoreceptor during the day and night phases of its diurnal rhythm.

Bibliography

BERTHOLF, L. M. 1931. The distribution of stimulative efficiency in the ultraviolet for the honey bee. J. Agr. Res., 43: 703–713.

———. 1932. The extent of the spectrum for *Drosophila* and the distribution of stimulative efficiency in it. Zeitschr. f. vergleich. Physiol., 18: 32–64.

CRESCITELLI, F. AND T. L. JAHN. 1939. The electrical response of the dark-adapted grasshopper eye to various intensities of illumination and to different qualities of light. Jour. Cell. and Comp. Physiol., 13: 105–112.

GRAHAM, C. H. AND H. K. HARTLINE. 1935. The response of single visual sesne cells to lights of different wavelengths. Jour. Gen. Physiol., 18: 917–931.

JAHN, T. L. 1946. The electroretinogram as a measure of wave length sensitivity to light. Jour. N. Y. Ent. Soc., 65: 1–8.

JAHN, T. L. AND F. CRESCITELLI. 1939. The electrical responses of the *Cecropia* moth eye. Jour. Cell. and Comp. Physiol., 13: 113–119.

———. 1940. Diurnal changes in the electrical response of the compound eye. Biol. Bull., 78: 42–52.

JAHN, T. L. AND V. J. WULFF. 1941a. Retinal pigment distribution in relation to a diurnal rhythm in the compound eye of *Dytiscus.* Proc. Soc. Exp. Biol. and Med., 48: 656–660.

———. 1941b. Influence of a visual diurnal rhythm on flicker response contours of *Dytiscus.* Proc. Soc. Exp. Biol. and Med., 48: 660–665.

———. 1943. Electrical aspects of a diurnal rhythm in the eye of Dytiscus fasciventris. Physiol. Zool., 16: 101–109.

———. 1946. The spectral sensitivity of *Dytiscus fasciventris.* Anat. Rec., 96 Suppl: 11.

WEISS, H. B., E. A. SORACI AND E. E. MCCOY, JR. 1941. Insect behavior to various wave lengths of light. Jour. N. Y. Ent. Soc., 49: 1–20; 149–151.

———. 1942. Insect behavior to various wave lengths of light. Jour. N. Y. Ent. Soc., 50: 1–35.

———. 1943a. Insect behavior to various wave lengths of light. Jour. N. Y. Ent. Soc., 51: 117–131.

Weiss, H. B. 1943b. Color perception in insects. Jour. Econ. Ent., 36: 1–7.

———. 1943c. The group behavior of 14,000 insects to colors. Ent. News, 54: 152–156.

———. 1944a. Insect responses to colors. Jour. N. Y. Ent. Soc., 52: 267–271.

Weiss, H. B., E. E. McCoy, Jr. and W. M. Boyd. 1944b. Group motor responses of adult and larval forms of insects to different wave lengths of light. Jour. N. Y. Ent. Soc., 52: 27–43.

———. 1945. Insect response to colors. Sci. Monthly, 61: 51–56.

Wulff, V. J. and T. L. Jahn. 1943. Intensity-EMF relations of the electroretinograms of bettles possessing a diurnal rhythm. Jour. Coll. and Comp. Physiol., 22: 189–194.

Wulff, V. J. 1943. Correlation of photochemical events with the action potential of the retina. Jour. Cell. and Comp. Physiol., 21: 319–326.